

# PERFORMANCE OF A NEWLY FORMULATED FILTER AIDS MATERIAL ON PARTICLE PENETRATION

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## ABSTRACT

*A study on the penetration of particle across a newly formulated filter aids material known as PrekotAC (combination of an adsorbent, activated carbon and pre-coating material, PreKot™) on PTFE filter media was carried out in a laboratory scale filtration test system. PrekotAC was evaluated based on the total penetrated particles across its filter cake under constant material loading of 0.2 mg/mm<sup>2</sup> and three different air flow rates of 4, 5 and 6 L/min. The ratio of total penetrated particles with and without the introduction of filter aids was observed and results showed that PrekotAC is capable to increase the collection efficiencies of ambient air particles compared to the performance of PTFE filter media alone. It was also found that PrekotAC has a better particle collection efficiencies compared to its original raw material activated carbon alone with PrekotAC 10:90 gives the lowest particle penetration among other combination of PrekotAC materials.*

**Keywords**— Filter aids, filter media, pre-coating material, penetration, PTFE

## 1. INTRODUCTION

Filter aids has been applied in air filtration system in order to increase the particle collection efficiency during filtration process. Filter aids consists of a group of inert materials used to coat the fabric as a 'barrier' for better protection of filter media as well as allowing a uniform air flow passing through the filter cake [1].

It was reported by previous authors that filter cake accumulated on the surface of a filter media acts as a new filter media that helps to increase the filtration efficiency. However, during cake filtration process, some particles do not participate in the formation of the filter cake. The particles either penetrating through or clog and block the pores of the filter media [2]. Therefore, understanding the parameters effecting the filtration efficiency is important in determining the best filter aids. Previous researcher stated that a good filter aids should not only able to extend the life span of a fabric filter, but it should have the least amount of

particle penetrated as well as help other particles from penetrating through the filter media [3].

This paper presents on the penetration of particles across a newly formulated filter aids material known as PrekotAC under constant material loading of 0.2 mg/mm<sup>2</sup> along with three different air flow rates of 4, 5, and 6 L/min (corresponds to filtration velocity,  $V_f$  of 5, 6 and 8 m/min respectively). PrekotAC was evaluated based on the total particle penetration across its filter cake as a mean of measuring its performance as a filter aids material in filtration process.

## 2. METHODOLOGY

### 2.1. Formulation of PrekotAC

Activated carbon used in this study is a coconut based material which is currently utilized as flue gas cleaning adsorbent product in the incineration process. On the other hand, PreKot™ (proprietary of AMR Environmental Sdn. Bhd.) is a commercially available pre-coating material consisting essentially of an amorphous hydrated glassy volcanic rock primarily fused aluminum silicate. Table 2.1 summarized the specifications of both materials that were used in this study.

Table 2.1 Specifications of activated carbon and PreKot™

Activated carbon	PreKot™
Form, color: Powder, black	Form, color: Powder, snowy white
Origin: Coal based	Fusion point: 1300-1400°
pH: 9-11	Softening point: 900-1100°
Ash content: 8% max	Thermal conductivity: Less than 0.0500 (kcal/mh°C) at 0°C
Bulk density: ~440 kg/m <sup>3</sup>	Bulk density: ~120 kg/m <sup>3</sup>

Both activated carbon and PreKot™ were dried in an oven (Mettler, Model UNB 200) for 24 hours at 110°C and mixed according to the proposed compositions as listed in Table 2.2.

Table 2.2 Formulation ratio of PreKot™ to activated carbon.

Ratio (wt%) PreKot™:Activated carbon
10:90
20:80
30:70
40:60

## 2.2. Filtration Test System

Figure 2.1 presents the experimental setup for the filtration system designed in this study, which consists of a dust feeder, filter media, pressure manometer, rotameter, and a vacuum pump. The filtration system was composed of two cylinders with a dust feeder on the top and a filter holder in between of the two cylinders. The volumetric airflow rate was controlled using the vacuum located at the end of the filtration system and monitored by a rotameter [4].

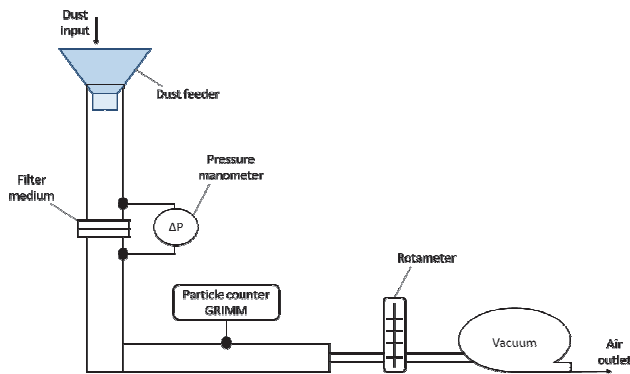


Figure 2.1 Laboratory scale filtration test system used in this study

The experiment was performed using PTFE filter media with total filtration area of 755 mm<sup>2</sup>. Table 2.3 presents the properties of the PTFE filter media used in this study.

Table 2.3 Properties of PTFE filter media used in this study

Material	PTFE
Weight (g/m <sup>2</sup> )	800
Thickness (mm)	1.3
Density (g/cm <sup>2</sup> )	0.62

The experiment was performed under three different air flow rates of 4, 5 and 6 L/min with the introduction of material loading 0.2 mg/mm<sup>2</sup>. The filtration velocity was determined by manipulating the air flow rate divided by the filtration area of the filter media. The particle penetration was monitored using GRIMM Aerosol Portable Laser Aerosol Spectrometer placed after the filter media. Similarly each of the experiment was repeated thrice and the overall experimental procedures are summarized in Table 2.4.

Table 2.4 Summary of the experimental procedures

Filter media	PTFE
Total filtration area	755 mm <sup>2</sup>
Material loading	0.2 mg/mm <sup>2</sup>
Air flow rate	4, 5, and 6 L/min
Filtration velocity	5, 6, and 8 m/min

## 3. RESULTS AND DISCUSSIONS

### 3.1. Collection efficiencies of PTFE filter media

Preliminarily in this study, the number of particle count in the ambient was measured before and after the filter media. Figure 3.1 presents the total number of particulate count per liter of ambient air (count/L) before and after filter media (without the introduction of filter aids) under various air flow rates of 4, 5, and 6 L/min. As in the figure, the average number of particles contained in ambient air before and after the filter media was  $3.0 \times 10^5$  and  $5.0 \times 10^4$ , respectively which revealed that the total number of particles penetrated across the filter media was reduced by six orders of magnitudes in all cases. The study illustrated that the number of particle found even in the ambient air decreases significantly after passing through the filter media which showed the ability of the filter media in capturing fine particles.

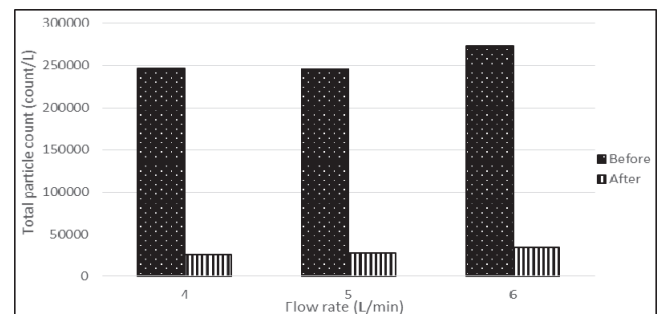


Figure 3.1 Total number of ambient air particles observed before and after filter media

As illustrated in Figure 3.1, the particle penetration is influenced by the air flow rate where the number of particles that penetrating through the filter media increases with flow rate from 4 to 6 L/min. A higher air flow rate leads to a bigger driving force causing more particles to penetrate through the open pores of the filter media as observed in the study.

It was reported that particle penetration at a lower air flow rate is less compared to the particle penetration at a higher flow rate [5]. The authors stated that higher air flow rate forces fine particles to easily permeate deep into the pores of the filter media compared to lower air flow rate thus increase the total number of particle penetration. Other authors also reported that penetration at lower air flow rate is small due to bridges of particles that formed because of low inertia and long retention time which limit particles

from passing through the filter media that leads to higher collection efficiency of particles [6].

Hence, it can be concluded that PTFE filter media itself has the ability to capture fine particles during filtration process. It was also observed that filtration efficiency is dependent on the air flow rate during filtration where higher air flow rate leads to increase in total particle penetration.

### 3.2. Efficiencies of PTFE filter media with respect to ambient particle size

Figure 3.2 presents the percentage of particle penetration (after PTFE filter media) against the ambient particle size under the three different air flow rates of 4, 5, and 6 L/min which showed that the particle penetration of particle size fraction of greater than 2.25  $\mu\text{m}$  is virtually zero in all cases. As in the figure, it was observed that approximately 80 percent of the particles that able to permeate through the filter media are those in the size range of  $0.265 \mu\text{m} \leq d_p < 0.375 \mu\text{m}$ .

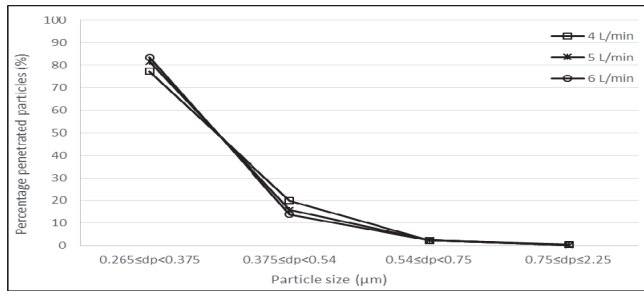


Figure 3.2 Penetration of ambient air in term of its particle size under three different air flow rates of 4, 5, and 6 L/min

The percentage of penetrated fine particles found in the ambient air was nearly the same for all air flow rates in this size range. This is expected as more of fine particles are found in the indoor ambient air which can easily escape through the pore size of the filter media. However, higher air flow rate leads to greater total particle penetration due to deep penetration of particles through the filter media. The penetration of particles with size bigger than 0.375  $\mu\text{m}$  was only 20 percent from the total penetrated particles. The decrement was observed due to particle blocking of open pores as well as the additional filter layer of filter cake on the surface of the filter media in all cases.

As reported by previous researcher the penetrating particle size decreases as filtration velocity (referring to air flow rate) increases because most penetrating particle shifts to a smaller particle size fraction. The authors also stated that, as velocity decreases it enhances the diffusion mechanism of the particles on the filter media resulting in lesser total particle penetration. On contrary, at higher velocity resulting in more particle penetration because it has bigger impaction mechanism [7]. Hence, as showed in the Figure 3.2, the number of penetration of fine and coarse particles

are increasing and decreasing, respectively as air flow rate increases.

As illustrated in Figure 3.2, the total particle penetration decreases as particle size increases in all cases and the penetration of particles greater or equal to 0.75  $\mu\text{m}$  was very minimal which is less than 1% compared to smaller particles. The findings also suggest that the penetration of particle greater than 2.25  $\mu\text{m}$  is virtually zero in all cases which showed the ability of the PTFE filter media itself in arresting fine dust particles. However, the collection efficiency is highly influenced by the air flow rate of filtration process. The higher the air flow rate is, the higher the total particle penetration becomes especially for fine particles.

It was also observed that the total penetrated fine particles at higher air flow rate is higher compared to lower air flow rate. This is due to deep penetration where fine particles can easily penetrating through the filter media under high air flow rate as in this case. In addition, total penetrated particles decreases as particle size increases in all cases as the first dendrites formed inside the filter media pores blocked incoming particles from passing through the filter media.

### 3.3. Higher collection efficiencies with PrekotAC

Figure 3.3 depicts the ratio of the number of penetrated particles through a PTFE fabric filter, with the introduction of filter aids materials under constant material loading of 0.2 mg/mm<sup>2</sup> with three different air flow rates of 4, 5 and 6 L/min. The ratio of the number of penetrated particles across the blank PTFE filter under various air flow rates was calculated based on Equation 3.1 [8].

$$\text{Ratio penetrated particles } (R_{pp}) = T_f/T_i \quad \dots \text{Equation 3.1}$$

Where;

- $R_{pp}$  = the ratio of the number of penetrated particles,
- $T_i$  = total number of ambient air penetrated without filter aids, and
- $T_f$  = total number of penetrated particles after filter aids was added

The  $R_{pp} < 1.0$  means that less particle penetrated through while  $R_{pp} > 1.0$  means poor filtration as higher amount of particles is able to penetrate compared to the fabric filter alone.

As in Figure 3.3,  $R_{pp} = 1.0$  marked with a dashed line is a ratio of an equal number of penetrated particles with respect to the blank PTFE fabric filter. As previously discussed, PTFE filter media is able to reduce the number of particles found in the ambient air. However, its collection performance increases with the addition of filter aids material (i.e  $R_{pp} < 1.0$ ) in the filtration process particularly at the lowest air flow rate of 4 L/min.

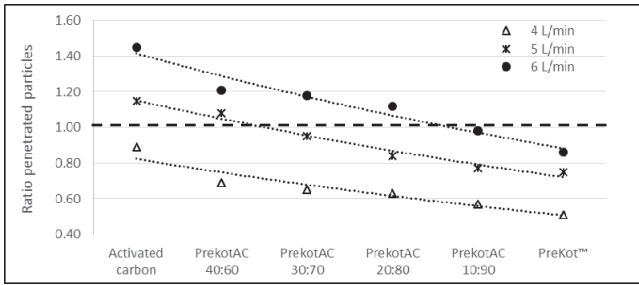


Figure 3.3 Ratio of total penetrated particles with and without addition of PrekotAC.

As illustrated in Figure 3.3, the original material of activated carbon retains the highest while PreKot™ has the lowest  $R_{pp}$  in all cases. It seems that the particle size distribution of the respective material play a major role in this finding. As reported by previous researcher, activated carbon and PreKot™ have a different characteristics in terms of its particle size distribution where activated carbon which mainly consists of fine particles (more than 80% of particles with size  $\leq 75 \mu m$ ) compared to PreKot™ (merely 20% of it is particles with size  $\leq 75 \mu m$ ). Thus, it is expected that activated carbon has higher  $R_{pp}$  compared to PreKot™ [8].

A similar finding was also reported that the collection efficiency for coarser particles are higher compared to finer particles. Lee *et al.* found that fine particles can easily penetrating through the filter media compared to coarser particles even using two different types of fabric filter [3,9].

In term of PrekotAC materials, PrekotAC 40:60 registered the highest while PrekotAC 10:90 retains the lowest  $R_{pp}$  in all cases. As shown in Figure 3.3, higher amount of PreKot™ in the newly formulated PrekotAC materials leads to higher  $R_{pp}$ . It was found that the characteristics of the PreKot™ itself which has an oddball shapes of a loosely pack material with larger size particles and porosity (as shown in Figure 3.4), leads to higher  $R_{pp}$  [10]. As observed, PrekotAC 10:90 presents a better collection efficiency among the other combination of PrekotAC mixtures.

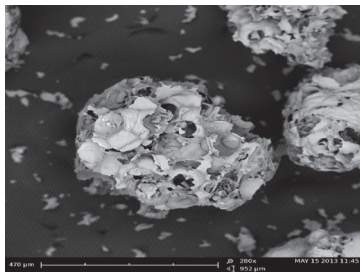


Figure 3.4 Micrographs view of PreKot™

As illustrated in the Figure 3.3, higher air flow rate leads to higher  $R_{pp}$  for all filter aids admixtures. The  $R_{pp}$  for all filter aids material was the lowest at 4 L/min and the highest at 6 L/min. This is similarly reported by other studies of increased in particle penetration with respect to higher

filtration velocity. The higher air flow rate forces more particles to penetrate deep into the filter media pores and therefore causes more particles to pass through the filter media, causing bigger total penetration.

The finding showed that PrekotAC has the ability to reduce the number of particles penetrated through a filter media. However, total particle penetration is dependent on the air flow rate of the filtration process where higher air flow rate leads to a higher total particle penetration. However, the utilization of PrekotAC mixture as filter aids and flue gas cleaning agent in the actual industrial application will be of greater advantage as a very low filtering velocity of 1.0 – 1.5 m/min is usually applied in the filtration system.

### 3.4. Efficiencies of PrekotAC filter aids material based on particle size

Figure 3.6 presents the percentage of penetrated particles through the filter media for filter aids material under a constant material loading of 0.2 mg/mm<sup>2</sup> and at various air flow rates of 4, 5, and 6 L/min which showed that the particle size fraction of greater than 1.18  $\mu m$  is completely collected. As previously observed (Figure 3.2), PTFE filter media is capable of completely collected ambient particle size greater than 2.25  $\mu m$  from passing through it. Interestingly as shown in Figure 3.6, only particles size lesser and equal to 1.18  $\mu m$  was able to penetrate through the filter media which illustrated that the application of filter aids helps to further remove fine particles compared to filter media alone. Thus, the addition of filter aids during the filtration process helps to increase the collection efficiency of sub-micron particle size fraction.

Filter aids have been widely applied in fabric filtration system as a ‘barrier’ to remove the sub-micron particles or impurities from the air gas stream [11]. Filter aids material has been applied in air filtration system as a pre-coating material to enhance the collection efficiency as well as overcome the wear and tear problem of fabric filter. Filter aids also helps to increase the filtration efficiency by forming a permeable filter cake layer for efficient operation against blinding and plugging of fabric filter. Thus, by adding filter aids in fabric filtration system, it helps to give a better filtration performance and reduces total penetrated particles.

Similarly, the study showed that the application of filter aids during the filtration system increases the filtration efficiency of a given filter media. As depicted in the figures, most penetrated particles were extremely fine in size of between 0.265  $\mu m$  and 0.375  $\mu m$  in all cases of the experiment representing 80 percent of the total number of penetrated particles.

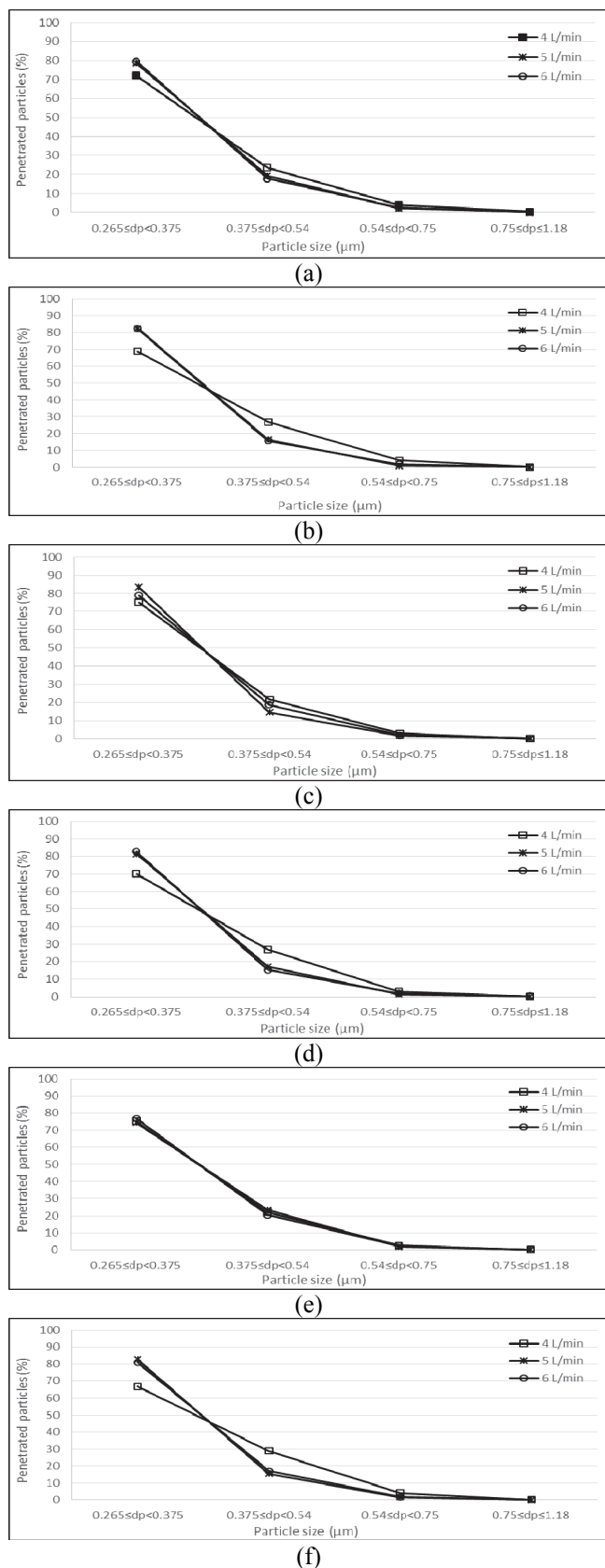


Figure 3.6 Percentage of penetrated particles under constant material loading of 0.2 mg/mm<sup>2</sup> and various air flow rates of 4, 5 and 6 L/min. (a) Activated carbon, (b) PrekotAC 10:90, (c) PrekotAC 20:80, (d) PrekotAC 30:70, (e) PrekotAC 40:60 and (f) PreKot™

It was also observed from Figure 3.6 that as flow rate increases, the percentage of the fine particles that penetrated through a filter media also increases. As can be seen from the figure, at higher air flow rate of 5 and 6 L/min, more of fine particles of  $0.265 \mu\text{m} \leq dp < 0.375 \mu\text{m}$  able to penetrated through the filter media compared to lower air flow rate of 4 L/min. However, the total penetration of particles with size range of  $0.375 \mu\text{m} \leq dp < 0.54 \mu\text{m}$ , was slightly higher at lower air flow rate of 4 L/min compared to higher air flow rate of 5 and 6 L/min. The results obtained are also similar to previous report where it was stated that the penetrating particle size decreases as filtration velocity increases because most penetrating particle shifts to a smaller particle size fraction

As observed by other authors, at higher air flow rate, the filter cake piled up with faster rate because high air flow rate leads to the higher kinetic energy of the dust particulate which forces many fine dust particles penetrated through the filter media leading to higher penetration of fine particles [12]. The results obtained in this study are also similar to those found elsewhere [9,13]. As observed by the authors, an increase in particle size will reduce the total particle that penetrating through the filter media. Hence, as expected, the penetration of particles with size range  $0.265 \mu\text{m} \leq dp < 0.375 \mu\text{m}$  retains the highest particle penetration percentage compared to coarser particles since fine particles can easily penetrating through a filter media.

#### 4. CONCLUSIONS

The study deals with the effect of adding PrekotAC as a filter aids material in fabric filtration system. Throughout the experiment, it was found that PrekotAC has the ability to reduce the total number of penetrated particles compares to the performance of PTFE filter media alone. Among these four PrekotAC mixtures, PrekotAC 10:90 retains the lowest  $R_{pp}$  even at the highest air flow rate of 6 L/min. The effect of the PreKot™ material itself which has a multi cellular shape with higher porosity had caused fine particles to easily penetrate through the material. It was also proven that the total number of penetrated particles is highly influenced by the air flow rate used during the filtration process. It was found that higher air flow rate leads to bigger total penetrated particles. However, In the actual processes, filter aids will be treated under a very low air flow rate of 1 – 1.5 L/min. Thus, it is expected that by adding PrekotAC during the processes will increase significantly.

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